3D-CDTI USER MANUAL

Flight Deck Research Group

NASA Ames Research Center

MS 262-2

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Last Update: November 3, 2003

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1.0 INTRODUCTION

The 3D-Cockpit Display of Traffic Information (3D-CDTI) is a flight deck tool that presents aircrew with:

- proximal traffic aircraft location, their current status and flight plan data
- strategic conflict detection and alerting
- automated conflict resolution strategies
- the facility to graphically plan manual route changes
- time-based, in-trail spacing on approach

The CDTI is manipulated via a touchpad on the flight deck, and by mouse when presented as part of a desktop flight simulator.

1.1 DOCUMENT PURPOSE

This manual is maintained to provide basic information on the CDTI for:

- pilots participating in research activities
- research partners in government and industry

1.2 DOCUMENT UPDATES

Document updates are available by visiting the Flight Deck Research Group at:

- http://human-factors.arc.nasa.gov/ihh/cdti/index.html

1.3 CONTACT INFORMATION

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2.0 DISPLAY BASICS

This section describes the CDTI's standard navigation elements and display controls.

2.1 STANDARD NAVIGATION ELEMENTS

The CDTI's standard navigation elements are referenced below, and described on the following pages.

Display 01 Standard navigation elements appearing on the CDTI.

01 Ground Speed (GS)
Indicated Air Speed (IAS)
Altitude (ALT)
Wind direction / Wind speed in knots

02 Current heading

03 Current display range (NM)

04 Next VOR / waypoint
Time to arrive at next VOR / waypoint (Zulu)
Distance to next VOR / waypoint

05 **Not defined**

06 **Not defined**

07 **Not defined**

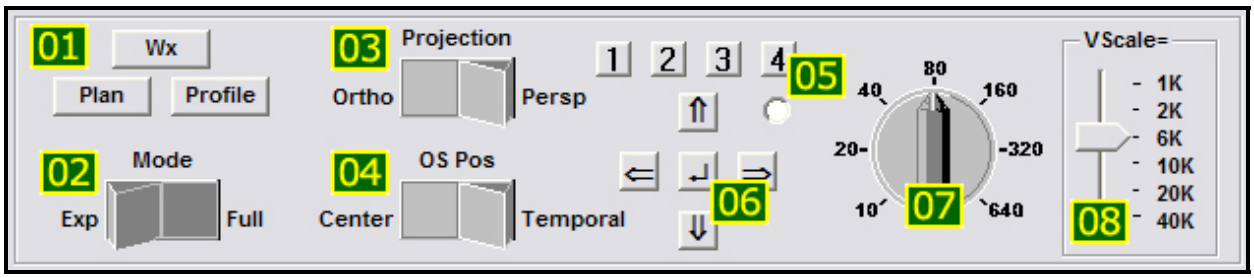
08 Display range mid-point (NM)

09 Desired heading – reflects heading changes input via the MCP

10 Ownship – Data tag for ownship can be toggled on/off
Operation – click chevron to turn ON / OFF

2.2 DISPLAY PANEL

The panel that appears with the CDTI controls a variety of display options, detailed below. Other display options are located on the tool bar below the CDTI.



Display 02 This panel controls how the CDTI looks.

01 Weather projection (Wx)
Plan view (Plan)
Profile view (Profile)
Operation – press to turn ON

02 Mode – Expanded view (Mode > Exp)
Mode – Full view (Mode > Full)
Operation – depress to turn ON

03 Projection – Orthographic view (Projection > Ortho)
Projection – Perspective view (Projection > Persp)
Operation – depress to turn ON

04 Ownship position – Center location (OS Pos > Center)
Ownship position – Temporal location (OS Pos > Temporal)
Operation – depress to turn ON

05 Display memory settings (1 through 4) – no label
Operation – Click radio button, then number, to set view

06 Ownship direction on display (4-way arrows) – no label
Return to last view ("enter" key button) – no label
Operation – press a button to reorient ownship

07 Range displayed – no label

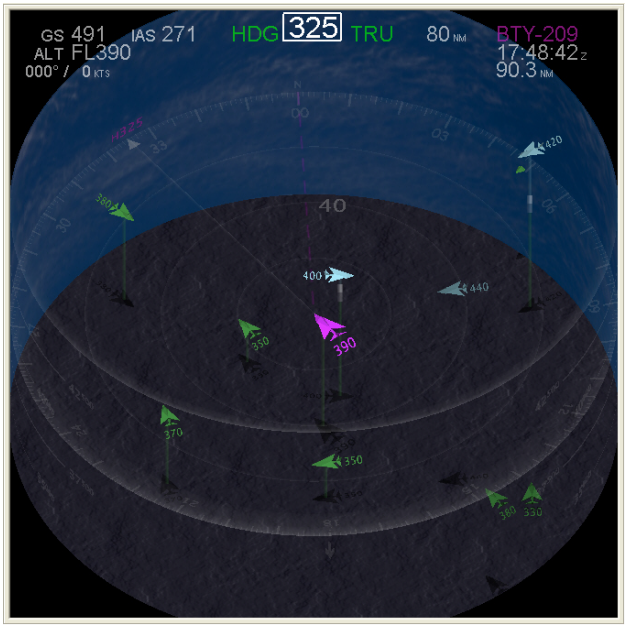
Operation – press number to set range

08 Vertical scale displayed (VScale=) – thousand feet above and below ownship

Operation – move slider to set range

2.3 3D-DISPLAY ACTIVATION

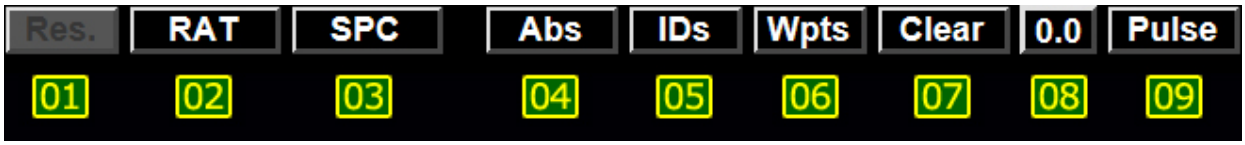
To 'rotate' the display into a 3D orientation, first set the "Mode > Full." Right-click and hold within the display area, move the mouse to modify the display's orientation, and release to set.



Display 03 3D CDTI view.

2.4 TOOL BAR

The panel that appears below the CDTI controls various display options and access to tools, detailed below. Other display options are located on the "panel" that accompanies the CDTI.



Display 04 This panel controls several display options and access to CDTI tools.

01 Automated resolutions (Res.)

Operation – press to access options

02 Route Analysis Tool (RAT)

Operation – press to turn ON / OFF

03 Spacing (SPC)

Operation – press to access / disengage

04 Absolute / Relative altitude tail tags (Abs / Rel)

Operation – press to toggle between Abs / Rel

05 Flight IDs (IDs)

Operation – press to toggle between all ON / OFF

06 Waypoints (Wpts)

Operation – press to toggle between all ON / OFF

07 Clear (Clear)

Operation – press to declutter display

08 Temporal length of pulse predictors (0.0)

Operation – Left click to decrease / right click to increase

09 Pulse (Pulse)

Operation – press to toggle between ON / OFF

3.0 AIRCRAFT SYMBOLOGY AND INTENT

This section describes the CDTI's aircraft symbology and intent communication.

3.1 OWNSHIP

Ownship position on the CDTI is indicated by a magenta chevron. Exact aircraft location lies at the tip of the chevron. If ownship come into conflict with another aircraft, the chevron turns yellow.

Symbology 01 Ownship symbol colors.

3.2 TRAFFIC

Traffic aircraft are represented by chevrons on the display. Exact aircraft location lies at the tip of each chevron.

3.2.1 ALTITUDE [COLOR CODING]

Traffic aircraft are displayed in one of three primary altitude-based colors.

Traffic 700 feet or more below ownship altitude are green.
Traffic less than 700 feet above or below ownship altitude are white.
Traffic 700 feet or more above ownship altitude are blue.
Traffic in conflict with ownship are yellow.

Symbology 02 Color-coding for traffic aircraft.

3.2.2 ALTITUDE [BRIGHTNESS CODING]

Traffic aircraft within 10 minutes of reaching ownship are "brighter" than other traffic aircraft on the display.

3.2.3 ALTITUDE [RELATIVE VS. ABSOLUTE]

Traffic within the vertical altitude band subject to surveillance each have an altitude tag (or tail tag). Absolute (Abs) altitude is represented by a two to three digit number (x 100 feet). When traffic altitude Relative (Rel) to ownship is indicated, a one or two digit number (x 100 feet) is presented, preceded by a + or – indicating whether above or below ownship's current altitude.

Click the Abs/Rel button on the tool bar to toggle between these two settings.

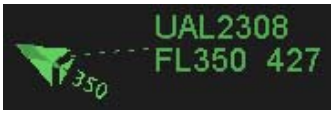
*Aircraft within the lateral surveillance range of ownship, but outside the probed altitude band are shown on the display. Altitude (tail) tags are **not** appended to these aircraft*.

3.2.4 ALTITUDE [CLIMB VS. DESCENT]

Traffic aircraft in a climb or descent of 200 ft/min or greater are indicated by the presence of an up or down arrow adjacent to the altitude tail tag.

3.2.5 DATA TAGS

Data tags can be displayed for traffic. Each tag contains the aircraft Flight ID (FID), current Flight Level (FL) in feet (x 100), and Ground Speed in knots.



Symbology 03 Traffic data tag.

Using a touchpad or mouse, place the cursor over the apex of the traffic symbol and dwell, highlighting the chevron. Left mouse click to display the data tag. Repeat this action to turn the data tag off.

To move the data tag, use the mouse to left-click-and-hold within the border of the tag and drag to the desired location. Release the mouse to 'drop' the data tag at its new location.

To turn on ***all*** data tags, click the IDs button on the tool bar to toggle data tags ON and OFF.

3.3 INTENT COMMUNICATION

Traffic intent is communicated to the CDTI operator via aircraft predictors and flight plans, described below. Other elements such as chevron heading and altitude tail tags provide secondary information as to intent.

3.3.1 PREDICTORS

For traffic aircraft broadcasting a flight plan, predictors indicate future position over time, along the planned path of travel. Click the Pulse button on the tool bar to toggle between predictors ON and OFF.

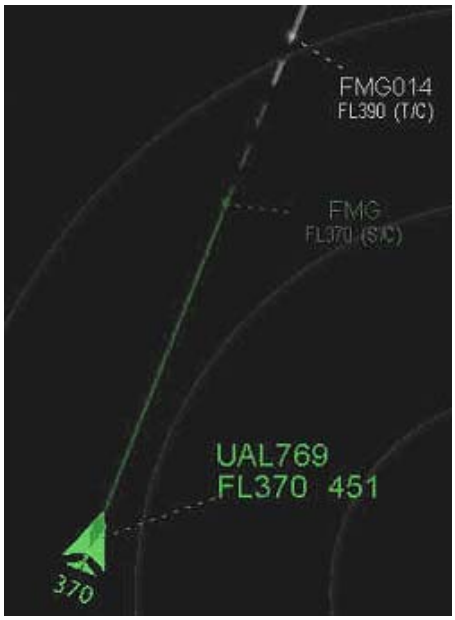
The pulse traveling the length of the predictor line correlates to the speed of the aircraft. All other elements (for example, winds) being equal, the pulse of an aircraft at 180 knots would be half as fast an aircraft traveling at 360 knots.

To alter the temporal value of pulse predictors, move the cursor over the time and left click to reduce the value. Right click to increase the value.

3.3.2 FLIGHT PLANS

Flight plans can be viewed for traffic within the broadcast range and altitude surveillance band of the CDTI. Using a touchpad or mouse, place the cursor over the apex of the traffic symbol and dwell, highlighting the chevron. Right mouse click to display the route. Repeat this action to turn the route off.

The flight plan will include waypoints and altitude changes. Altitude change segments are indicated by a Start of Climb (S/C) and Bottom of Climb (B/C), Top of Descent (T/D) and Bottom of Descent (B/D), with a dotted line between.



Symbology 04 Traffic flight plan.

Note: Intent information is color coded relative to the position and altitude of ownship.

4.0 CONFLICT DETECTION, ALERTING AND RESOLUTION

The CDTI provides strategic conflict detection. ***It is not designed for tactical conflict detection or resolution.***

4.1 CONFLICT DETECTION

Embedded within the CDTI is logic that detects conflicts, assigns an alert level, and communicates this to the flight crew. The logic takes advantage of intent information in the form of flight plans, when available. In the absence of flight plan data the conflict detection logic operates based on aircraft state information – current heading, altitude and speed.

4.2 CONFLICT ALERTING

When a conflict is detected, the ownship symbol turns yellow. The aircraft in conflict with ownship also turns yellow, and its data block appears. The traffic aircraft data block can not be disabled (turned off) until the conflict is resolved.

4.2.1 ALERTING LEVELS

A **LEVEL 1** conflict alert is best characterized as being either:

1A. Conflict Probability: **Moderate**	Temporal Proximity: **Far Term**
1B. Conflict Probability: **Low**	Temporal Proximity: **Near Term**

A level 1 conflict results in the ownship and traffic chevrons turning yellow.

A **LEVEL 2** conflict alert is best characterized as being either:

2A. Conflict Probability: **Moderate**	Temporal Proximity: **Middle Term**
2B. Conflict Probability: **High**	Temporal Proximity: **Far Term**

A level 2 conflict results in the ownship and traffic chevrons turning yellow, with a "halo" appearing around the traffic chevron.

A **LEVEL 3** conflict alert is best characterized as being:

3A. Conflict Probability: **High**	Temporal Proximity: **Near Term**
3B. Conflict Probability: **High**	Temporal Proximity: **Middle Term**

A level 3 conflict results in the ownship and traffic chevrons turning yellow, with a "halo" appearing around the traffic chevron. Intersecting conflict predictor lines and over-lapping LOS 'rings' appear during a level 3 conflict.

4.3 AUTOMATED CONFLICT RESOLUTION

In the event of a traffic conflict, the resolution (Res.) button in the tool bar turns yellow. This indicates ownship is the 'burdened' aircraft – that is, it is required to resolve the conflict. Clicking on the button will produce a list of resolution alternatives. The details of each resolution, in terms of heading, speed, or altitude change are indicated. Clicking on a resolution alternative will display the change on the CDTI proper. The list of resolution strategies remain valid and executable for 1 minute from when first presented.

The first (uppermost) resolution strategy in the list is the most efficient in terms of minimizing any course change, fuel usage, or deviation from an existing RTA (Required Time of Arrival). "Executing" a resolution strategy will update ownship's flight plan.

The interface elements of an automated conflict resolution are detailed on the following page.

CDR 01 Automated resolution elements.

01 Time to loss of separation (ALERT 00:00)

02 List of resolution strategies. Green background indicates currently displayed route

03 **Not defined**

Operation – press to…

04 Datalink – Transmits the route to ATC for approval

Operation – press to transmit

05 Execute – Executes the route on the CDTI

Operation – press to transmit

06 **Not defined**

07 **Not defined**

08 Current resolution strategy route

5.0 ROUTE ANALYSIS TOOL (RAT)

The Route Analysis Tool facilitates 1) in-flight, flight crew modification of flight plans, 2) submission of proposed flight plan changes to Air Traffic Control (ATC), 3) receipt of flight plan modifications from ATC, and 4) execution of flight plan changes in the following circumstances:

- without "approval" when in free flight,
- when first approved by ATC in limited free flight operations, or
- upon receipt (uplink) from ATC, with the concurrence of the flight deck.

Appropriate uses for the RAT include the planning and implementation of flight plan changes to 1) resolve strategic conflicts with other aircraft, 2) avoid weather, 3) take advantage of winds, 4) make use of more direct routing options when available, and 5) to avoid dynamic Special Use Airspace (SUA).

5.1 RAT WAYPOINT TABLE

Upon activation of the RAT, a table appears on the CDTI. The interface elements are detailed below.

RAT 01 The RAT waypoint table.

01 Left / Right arrows – Waypoint access

Operation – Press to cycle ID

02 Up / Down arrow – Expand and collapse table

Operation – Press to activate

03 Required Time of Arrival (RTA) – RTA at a VOR / waypoint

Operation – Click on numbers to highlight. Use up and down arrows to change

04 Estimated Time of Arrival (ETA) – ETA at the VOR / waypoint

05 Distance (Dist) – **Not defined**

Operation – Use up and down arrows to change

06 Altitude (Alt) – To make an altitude change at the designated waypoint

Operation – Use up and down arrows to change

5.2 LATERAL ROUTE MODIFICATIONS

The lateral path of ownship can be modified in three ways. An existing waypoint in the flight plan can be moved, a new waypoint created (and moved), or a waypoint deleted from the flight plan.

5.2.1 MOVING A WAYPOINT

Waypoints along a route can be selected and moved, creating a new path.

Step 1 – Turn the RAT on and move the cursor over an existing waypoint.

Step 2 – Click and hold on the highlighted waypoint. Drag the waypoint to a new location and 'drop' it.

Step 3 – Press Enter, then Execute on the tool bar.

RAT 02 Moving a waypoint. Route is ready to "Execute."

Note: When a proposed route is datalinked to ATC for review, it remains on the CDTI, in gray, until a reply has been received from the ground or the route passes the execution threshold – the small dot on the lubber line forward of ownship.

5.2.2 CREATING A WAYPOINT

Step 1 – Turn the RAT on, dwell over the route, and click when the arrow is over the desired location. A waypoint will be inserted.

Step 2 – Review the location of the waypoint. It can be dragged along the route path, or off to either side of the existing route.

Step 3 – Press Enter, then Execute when all route modifications are complete.

RAT 03 Creating a waypoint.

5.2.3 DELETING A WAYPOINT

Step 1 – Turn the RAT on and dwell over the waypoint on the route.
Step 2 – With the waypoint highlighted, right click once.
Step 3 – Press Enter, then Execute when all route modifications are complete.

5.3 VERTICAL ROUTE MODIFICATIONS

Step 1 – Create a waypoint along the route (see above), or select an existing waypoint.
Step 2 – Use the up and down arrows next to "Alt" in the waypoint table, to enter the desired altitude. A second (climb or descent transition) waypoint is automatically created.
Step 3 – Review the altitude change segment on the CDTI. Press Enter, then Execute when all route modifications are complete.

Note: The altitude change segment can be moved along the ownship route. Left click and hold, drop to re-locate.

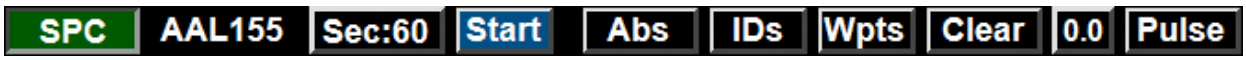
6.0 PDA SPACING

Paired Dependent Approach (PDA) Spacing is the initiation and execution of in-trail following during approach to landing. The goal of PDA spacing is to safely maximize the number of aircraft that can land within a given time. To achieve this, inter-aircraft spacing is optimized, such that aircraft cross the runway threshold with minimal 'lost' time between touch-downs.

6.1 SPACING INITIATION

Initiating spacing requires ATC first issue ownship a "lead" aircraft to follow, along with a time-in-trail. Flight crew begins PDA Spacing by:

- Clicking the "SPC" button on the tool bar
- Selecting (clicking on) the lead aircraft on the CDTI
- Modifying the spacing interval (time value) assigned by ATC
  - Left mouse click to decrease
  - Right mouse click to increase
- Clicking "Start" on the tool bar

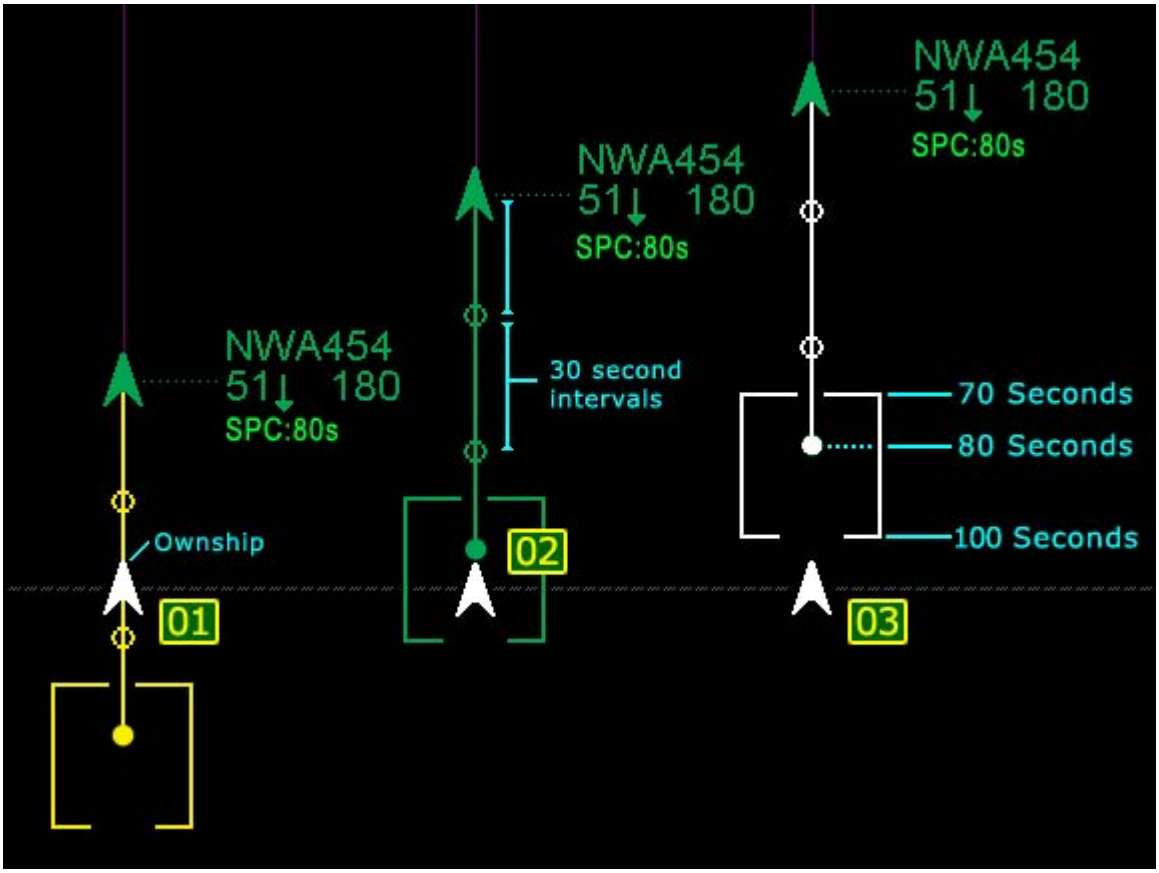


PDA 01 PDA Spacing is ready to be "Start"(ed).

The CDTI then calculates the required ownship speed for maintenance of the correct time interval ("PDA Processing" appears on the CDTI top left during data collection), and manipulates the auto-throttles appropriately ("CMD A/T" appears top left of CDTI). If a 'gap' exists the CDTI will increase ownship speed. If ownship is too close, the CDTI will slow ownship.

6.2 SPACING MONITORING

As there are instances when it is appropriate and/or necessary that flight crew intervene in a PDA operation, feedback on the CDTI is designed to facilitate this, and is described below.



PDA 02 PDA Spacing box colors are dependent on ownship position relative to the required temporal spacing value (80 seconds in the illustrated example).

01 If ownship is > 10 seconds ahead of the required temporal spacing value, the spacing box turns yellow.

02 When ownship is ≤ 10 seconds ahead of the required temporal spacing value, or ≤ 20 seconds behind the required temporal spacing value, the spacing box turns green.

03 If ownship is > 20 seconds behind the required temporal spacing value, the spacing box turns white.

7.0 DAG-TM

Distributed Air/Ground – Traffic Management (DAG-TM) is a NAS concept in which flight crews, ATC, and AOCs employ distributed decision-making to safely facilitate user preferences and increase system capacity. The goal of DAG-TM is to enhance user flexibility/efficiency and increase system capacity, without adversely affecting system safety or restricting user accessibility to the NAS.

Known DAG-related issues relevant to CDTI use are outlined below:

CDTI/MACS COMPONENTS

Starting a simulation trial, the following component panels should be present on-screen for all MACS/CDTI pilots:

MACS: PFD
MCP
CDU
Flaps/Gear
Datalink Controls
Datalink Display
Controlled Aircraft Panel

CDTI: CDTI Display
Display Tool Panel
Radio

ROUTE EXECUTION

Should ATC uplink to ownship, approval to load and execute an amended route, DAG pilots should always ensure that "Exec(ute)" on the FMS is pressed. The exception to this is when an RTA is entered and executed via the CDTI. This input ***does not*** require a final "Exec(ute)" on the FMS.

RTA COMPLIANCE - I

If an ownship route modification is required to meet an RTA, DAG pilots should plan the change using the CDTI, datalink the modification request to ATC, and upon approval, "Exec(ute)" the new routing.

RTA COMPLIANCE - II

A Required Time of Arrival (RTA) clearance, once entered and executed in the CDTI, is indicated lower right on the CDTI. Ownship compliance with the RTA is indicated by... **Not defined**

TOP OF DESCENT

For information purposes only, Top of Descent (ToD) is indicated along ownship route on the CDTI, and appears in the waypoint table. DAG pilots ***should not modify*** ToD on the CDTI or in the attendant waypoint table.

WEATHER

Weather information is available on the CDTI by pressing the Wx button on the display panel. Updates to the weather data are… **Not defined**

WINDS

A wind file is used in DAG studies, to simulate this weather element. Winds aloft are best described as being… **Not defined**